"Wallin, Sharon"
<WallinSL@cdm.com>
07/13/2007 05:02 PM

To Christopher Lichens/R9/USEPA/US@EPA

cc <LParnass@dtsc.ca.gov>, <tperina@ch2m.com>, <edm@demaximis.com>, "Chamberlin, David" <ChamberlinDC@cdm.com>, "Lavelle, James"

bcc

Subject Submittal of Tech Memo for Additional Ambient Air Analysis Requested by USEPA

History: This message has been forwarded.

Hi Chris - the attached documents provide the additional information requested by USEPA at the June 28th meeting regarding USEPA comments to the Human Health Risk Assessment Report for On-Site Soils for the Omega Chemcial Superfund Site. If you have any questions regarding the attached, please feel free to call.

Regards,

Sharon Wallin, P.G.
CDM
18581 Teller Ave., Suite 200
Irvine, CA 92612

Phone 949 / 752-5452
Direct Phone 949 / 930-2941
Fax 949 / 752-1307
email wallinsl@cdm.com

<<Attachment A-1.pdf>> <<Attachment A-2 Site Resident Omega_SG-ADV-Feb04_Example PCE.pdf>> <<Attachment A-3 Site Resident Omega_SG-ADV-Feb04_Example PCE.pdf>> <<Omega TM Ambient Air3 (3) (2).doc>>


Attachment A-1.pdf


Attachment A-2 Site Resident Omega_SG-ADV-Feb04_Example PCE.pdf


Attachment A-3 Site Resident Omega_SG-ADV-Feb04_Example PCE.pdf


Omega TM Ambient Air3 (3) (2).doc

18581 Teller Avenue, Suite 200
Irvine, California 92612
tel: 949 752-5452
fax: 949 752-1307

July 13, 2007

Chris Lichens, Superfund Project Manager
USEPA REGION IX
75 Hawthorne Street
San Francisco, CA 94105

Subject: Technical Memorandum for Ambient and Indoor Air Analysis for Human Health Risk Assessment for On-Site Soils, Omega Chemical Superfund Site in Response to Meeting with EPA on June 28, 2007

Dear Mr. Lichens:

OPOG and EPA met on June 28, 2007 to discuss EPA comments dated June 8, 2007 to the Human Health Risk Assessment for On-Site Soils, Omega Chemical Superfund Site, CDM, dated April 17, 2007. One of the primary issues discussed at this meeting was the approach regarding the ambient air exposure pathway. This memorandum outlines the approach and equations for estimating future ambient air concentrations from soil gas concentrations for both chronic and short-term exposure scenarios. Parameters to be used in these calculations and an example calculation using PCE at the Omega parcel are also provided. The Johnson and Ettinger (J&E) model will be used for estimating future indoor air concentrations from soil gas concentrations. Parameters for use in the J&E model are also provided.

Ambient Air - Chronic Exposure Scenario

Karami, et al. (1987) along with the USEPA Draft Soil Screening Guidance (1994) were used to estimate ambient air concentrations for chronic exposure scenarios (residents and commercial workers). According to Karami, et al. (1987), assuming that the concentration at the surface is very small, vapor flux through soil can be estimated using the equation:

$$J = -D_s \times (-C_s)/L \qquad \text{(Eq. 1-1)}$$

Where

$$D_s = D_i (P_a^{10/3}/P_t^2) \qquad \text{(Eqn. 1-2)}$$

$$P_a = P_t - P_w \qquad \text{(Eqn. 1-3)}$$

The emission rate of the site can then be calculated by:

$$E = J \times A_{site} \qquad \text{(Eqn. 1-4)}$$

Assuming a simple box model, the ambient air concentration can then be calculated using the following equation:

$$C_{air} = E / (L_s \times W \times D_H) \qquad \text{(Eqn. 1-5)}$$

Proposed parameters (default and site-specific) for use in the equations are provided in Table 1.

Table 1
Input Parameters for Estimating Ambient Air Concentrations for Chronic Exposure Scenarios (Residents and Commercial Workers)

Variable	Description	Default Value	Proposed Site-Specific Value	Source
L	Depth of the soil layer	Site-specific	9.144 m (30 ft)	Site data
D_i	vapor diffusion coefficient in air	chemical specific	7.2E-02 cm^2/s (7.2E-06 m^2/s) for PCE	J&E model value for PCE (USEPA 2004)
P_t	Total porosity	Site-specific	0.399 m^3/m^3	J&E model value for loam (USEPA 2004)
P_w	Water-filled porosity	Site-specific	0.148 m^3/m^3	J&E model value for loam (USEPA 2004)
P_a	Air-filled porosity	Site-specific	0.251 m^3/m^3	Calculated from USEPA 2002 Eqn 1-3
C_s	Concentration in the air at depth	Site-specific and chemical specific	1.12E-3 kg/m^3 (1,121,994 ug/m^3) for PCE	95 UCL for soil gas concentrations ranging from 5 to 6 feet deep for samples collected on the Omega site parcel
A_{site}	Site area	0.5 acres	1 acre	Site specific
D_s	Apparent steady state vapor diffusion coefficient	Site-specific and chemical specific	3.28E-02 cm^2/s (3.28E-06 m^2/s) for PCE	Calculated from Millington and Quirk (1961) Eqn 1-2
J	Vapor flux through soil	Site-specific	2.63E-10 $kg/m^2/s$	Calculated from Eqn. 1-1
E	Emission rate	Site-specific	1.06E-06 kg/s	Calculated from Eqn. 1-4
L_s	Length of side	Site-specific	63.6 m^2	Site–specific - Square root of 1 acre site
V	Downwind length proportional	Site-specific	1.45 m	

Variable	Description	Default Value	Proposed Site-Specific Value	Source
	to wind speed (wind speed of 1.65 m/s)			
D_H	Diffusion Height	Site-specific	2 m	Breathing zone
C_{air}	Concentration in Ambient Air	Site-specific and chemical specific	8.83E-9 kg/m^3 (8.83 ug/m^3) for PCE	Calculated from Eqn. 1-5

kg/m^3 = kilograms per cubic meter
m^3/m^3 = cubic meter per cubic meter
$kg/m^2/s$ = = kilograms per square meter per second
ft = feet
m = meter
bgs = below ground surface
USEPA = United States Environmental Protection Agency

For PCE for the Omega parcel, the 95 UCL soil gas concentration from 5 to 6 ft bgs is 1,121,994 ug/m^3 (1.12E-3 kg/m^3) results in an ambient air concentration is 8.83 ug/m^3.

Ambient Air - Short-term Exposure Scenario

For estimating ambient air concentrations for short-term exposure scenario (construction worker), measure soil gas concentrations were back calculated to estimate a soil source concentration. This soil concentration was then combined with a volatilization factor to calculate an ambient air concentration.

For the construction worker, it was assumed that the contamination extended from the surface to the 30-foot clay layer. The 95 UCL for soil gas concentrations ranging from 5 to 30 feet deep for samples collected on the Omega site parcel is 733,374 ug/m^3. To calculate a soil source concentration from this soil gas concentration the following equation was used:

$$C_r = C_{source} * (P_w+K_d*P_b+H'*P_a) / (H'*P_b) \qquad \text{Eqn. 2-1}$$

Proposed parameters (default and site-specific) for use in Equation 2-1 are provided in Table 2.

Table 2
Input Parameters for Estimating Soil Concentrations from Soil Gas Concentrations

Variable	Description	Default Value	Proposed Site-Specific Value	Source
C_{source}	vapor concentration at soil source	Site-specific and chemical specific	7.33E-04 g/cm^3 (733,374 ug/m^3) for PCE	95 UCL for soil gas concentrations ranging from 5 to 30 feet deep for samples collected on the Omega site parcel
P_b	bulk dry soil density	Site-specific	1.59 g/cm^3	J&E model value for loam (USEPA 2004)
P_t	Total porosity	Site-specific	0.399 m^3/m^3	J&E model value for loam (USEPA 2004)
P_a	Air-filled porosity	Site-specific	0.251 m^3/m^3	Calculated from USEPA 2002 Eqn 1-3
P_w	Water-filled porosity	Site-specific	0.148 m^3/m^3	J&E model value for loam (USEPA 2004)
K_d	Soil-water partition coefficient	3.10E-01 cm^3/g	Default	Calculated from K_{oc} x f_{oc}
K_{oc}	Organic carbon partition coefficient (g/cm^3)	1.55E+02 cm^3/g	Default	J&E model value for PCE (USEPA 2004)
f_{oc}	Fraction of organic carbon for loam (unitless)	0.002 for loam	Default	
H'	Henry's law constant (unitless)	chemical specific	7.53E-01 for PCE	J&E model value for PCE (USEPA 2004)
C_r	soil concentration (g/g)	Site-specific and chemical specific	5.09E-04 g/g (509 mg/kg) for PCE	Calculated from Eqn 2-1

ug/m^3 = micrograms per cubic meter
m^3/m^3 = cubic meter per cubic meter
g/cm^3 = = grams per cubic centimeter
cm^3/g = cubic centimeter per gram
bgs = below ground surface
USEPA = United States Environmental Protection Agency

Entering these values into Equation 2-1, the corresponding soil source concentration is 5.09E-4 g/g (509 mg/kg).

To determine an ambient air concentration from this soil concentration, the soil concentration was input into the RBCA Tool Kit for Chemical Releases, Version 1.2 (1999). Proposed parameters (default and site-specific) for use in the RBCA Tool Kit model are provided in Table 3.

Table 3
Input Parameters for Estimating Volatilization Factor for PCE

Description	Default Value	Proposed Site-Specific Value	Source
Soil concentration	Site-specific	509 mg/kg	Calculated from 95 UCL for soil gas concentrations ranging from 5 to 30 feet deep for samples collected on the Omega site parcel
Depth to top of affected soils	Site-specific	152.4 cm (5 ft)	Site data
Depth to base of affected soils	Site-specific	914.4 cm (30 ft)	Site data
Affected soil area	Site-specific	40,500,000 cm^2 (1 acre)	Site data
Length of affected soil parallel to assumed wind direction	Site-specific	6,361 cm	Site data
bulk dry soil density	Site-specific	1.59 g/cm^3	J&E model value for loam (USEPA 2004)
Total porosity	Site-specific	0.399 m^3/m^3	J&E model value for loam (USEPA 2004)
Volumetric Air Content – Vadose Zone	Site-specific	0.251 m^3/m^3	Calculated from total porosity – volumetric water content
Volumetric Water Content – Vadose Zone	Site-specific	0.148 m^3/m^3	J&E model value for loam (USEPA 2004)
Volumetric Air Content – Capillary Fringe	Site-specific	0.067 m^3/m^3	Calculated from total porosity – volumetric water content
Volumetric Water Content – Capillary Fringe	Site-specific	0.332 m^3/m^3	J&E guidance value for loam (USEPA 2004)
Vertical hydraulic conductivity	Site-specific	12 cm/d	J&E guidance value for loam (USEPA 2004)
Vapor permeability	Site-specific	1.6E-9 cm^2	J&E guidance value for loam (USEPA 2004)
Capillary zone thickness	Site-specific	37.5 cm	J&E guidance value for loam (USEPA 2004)
Fraction of organic carbon for loam (unitless)	Site-specific	0.002	
Air mixing zone height	200 cm	Default	Breathing zone height
Ambient air velocity in mixing zone	Site-specific	33 cm/s	$1/5^{th}$ the value of the site average air velocity of 1.65 m/s to account for being in an excavation

mg/kg = milligram per kilogram
cm = centimeter
ft = feet
cm^2 = square centimeter
g/cm^3 = = grams per cubic centimeter
m^3/m^3 = cubic meter per cubic meter
cm/d = centimeters per day
cm/s = centimeters per second
USEPA = United States Environmental Protection Agency

The ambient air concentration is then reported in box 3 of the RBCA Tool Kit results page. Thus, based on a PCE soil gas concentration of 733,374 ug/m^3, the ambient air concentration is 750 ug/m^3. RBCA Tool Kit printouts are provided as Attachment A-2.

Indoor Air - Johnson and Ettinger Model

Inhalation of indoor air was evaluated for current commercial/industrial workers using measured indoor air concentrations to directly estimate risk related to indoor air exposure. However, because new buildings may be constructed in the future and there are no existing residential homes on the site, inhalation of indoor air for future commercial/industrial workers and hypothetical residents will be evaluated using measured concentrations of VOCs in soil gas modeled to represent indoor air concentrations. The USEPA advanced soil gas spreadsheet implementation of (WindowsTM - Excel) the Johnson and Ettinger vapor intrusion model (SG_ADV_Feb04.xls last modified February, 2004) was used to estimate potential indoor air concentrations from soil gas concentrations by calculating flux of chemicals through a foundation, taking into account building size and ventilation. Site-specific criteria to be used in the model are summarized in Table 4:

Table 4
Johnson and Ettinger Model Input Parameters for Site-Specific Screening

Variable	Description	Default Value	Proposed Site-Specific Value	Source
C_{sg}	Soil gas concentrations	Site-specific	1.12E-3 kg/m^3 (1,121,994 ug/m^3) for PCE	95 UCL for soil gas concentrations ranging from 5 to 6 feet deep for samples collected on the Omega site parcel
θ_t	Soil total porosity	Site-specific	0.399	Model default for Loam soil
θ_w	Soil water-filled porosity	Site-specific	0.148	Model default for Loam soil
θ_a	Soil air-filled porosity	Site-specific	0.251	Model default for Loam soil
ρ_s	Soil dry bulk density	Site-specific	1.59	Model default for

Variable	Description	Default Value	Proposed Site-Specific Value	Source
				Loam soil
k	Soil intrinsic permeability	Site-specific	2.29E-09	Model default for Loam soil
° T	Soil and groundwater temperature	Site-specific	67°F (19.4°C)	Figure A-1 from DTSC 2005
ΔP	Indoor – outdoor pressure differential	40 g/cm-s_2	Default	USEPA 2004
η	Crack-to-total area ratio	0.005	0.0004	Calculated based on recommended 0.1 cm crack width (USEPA 2003). See note (1)
E_b	Indoor air exchange rate - residential	0.5 / hour	Default	USEPA 1997
E_b	Indoor air exchange rate - commercial	1.0 / hour	Default	CEC 2001
L_{crack}	Foundation slab thickness	Site-specific	15 cm	
L_b,W_b	Building dimensions – length x width	1000 cm x 1000 cm	Default	DTSC 2005
H_b	Building dimension – height - residential	244 cm (8 ft)	Default	DTSC 2005
	Building dimension – height - commercial	none	276 cm (9 ft)	
L_f	Foundation depth below grade – building with no basement	15 cm	Default	USEPA 2004
Ls	Soil gas sampling depth below grade	Site-specific	152.4 cm (5 ft)	Site data
ED, EF, ET	Exposure Duration, Exposure Frequency, Exposure Time – residential	30 years, 350 days/yr, 24 hrs/day	Default	USEPA 1997
ED, EF, ET	Exposure Duration, Exposure Frequency, Exposure Time - commercial	none	25 years, 250 days/yr, 8 hrs/day	USEPA 1997

USEPA = United States Environmental Protection Agency
DTSC = Department of Toxic Substances Control
CEC = California Energy Commission
cm = centimeters
ft = feet
g/cm-s^2 = grams per centimeter – seconds squared
Note:

(1) For future buildings, a soil gas advection rate of 5 liters per minute should be used, as proportionally increased for future building size, rather than the defaults for indoor – outdoor pressure differential, crack-to-total area ratio, and foundation thickness.

Other model input parameters include the physical/chemical properties of COPCs. Chemical properties (such as air and water diffusivities and Henry's law constants) were either found in the model, researched for inclusion in the model or calculated using the references provided in the user's guide for the Johnson and Ettinger Model (USEPA, 2004). Model defaults were used when site specific values were not available.

The building concentration ($C_{building}$) reported on the INTERCALCs sheet of the J&E model was used as the indoor air concentration that the receptor is exposed to indoors.

An example J&E model run is attached as Attachment A-3.

References

California Energy Commission. 2001. *Manual for Compliance with the 2001 Energy Efficiency Standards (for Nonresidential Buildings, High-Rise Residential Buildings, and Hotels/Motels).* Document No. P400-01-032. August.

DTSC. 2005. *Guidance for the Evaluation and Mitigation of Subsurface Vapor Intrusion to Indoor Air.* February 7.

Groundwater Services Inc. 1999. RBCA Tool Kit for Chemical Releases, Version 1.2.

Karami, Ali A.; Walter J. Farmer, and Mark M. Cliath. 1987. *Vapor Phase Diffusion of Benzene in Soil.* Journal of Environmental Quality, Vol. 16, no. 1, 1987. pp. 38-43.

Millington, R.J. and J.P. Quirk. 1961. *Permeability of porous solids.* Trans. Faraday Soc. Vol. 57. pp. 1200-1207.

USEPA. 1994. Office of Emergency and Remedial Response. *Technical Background Document for Draft Soil Screening Level Guidance.* March.

USEPA. 1997. *Exposure Factors Handbook. Volume 1. General Factors.* Office of Research and Development. EPA/600/P-95/002Fa. August.

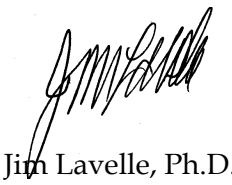
USEPA. 2002. *Evaluating the Vapor Intrusion into Indoor Air*. EPA530-F-02-052. November.

USEPA. 2002. *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites. OSWER 9355.4-24*. December.

USEPA. 2004. *User's Guide for Evaluating Subsurface Vapor Intrusion into Buildings*. February 22.

USEPA. 2004. *USEPA Region 9 Preliminary Remediation Goals Tables*. October.

Very truly yours,



Jim Lavelle, Ph.D.
Senior Risk Assessor and Toxicologist
Camp Dresser & McKee Inc.

cc: Ed Modiano, Project Coordinator
Tom Perina, CH2M Hill
Lori Parnass, DTSC
Sharon Wallin, CDM
Kassandra Tzou, CDM

Attachments

A-1 PCE data for Calculations of 95UCL for Omega Site Data 5 to 6 feet bgs and 5 to 30 ft bgs

A-2 PCE Example of RBCA Tool Kit Spreadsheet Model

A-3 PCE Example of Johnson and Ettinger Model Results for Soil Gas to Indoor Air

Attachment A-3
PCE Example of Johnson and Ettinger Model Results for
Soil Gas to Indoor Air for Hypothetical Residential Exposure

CAS #	Chemical	Soil Gas Concentration		EPC Cbuilding ug/m^3	Minimum Cbuilding ug/m^3	Unit risk factor, URF ($\mu g/m^3$)$^{-1}$	CSF (mg/kg/day)$^{-1}$	Reference conc., RfC (mg/m^3)	RfD (mg/kg/day)
		EPC ug/m^3	Minimum ug/m^3						
127184	TETRACHLOROETHENE	1,121,994	16,272	7.82E+02	1.13E+01	5.90E-06	2.07E-02	3.50E-02	1.00E-02

(1) Assumed an average soil temperature of 19.4oC per Figure A-1 in DTSC Indoor Air Guidance (Feb. 2005)
(2) Assumed the soil was loam.
(3) Default exposure frequency and duration of 350 days per year and 30 years typical for a resident and exposure time of 24 hrs/day.
(4) Default building size of 10 meters length, 10 meters width, and 8-foot (244 cm) ceiling height was used.
(5) Building air exchange for resident home of 0.5 per hour.

SG-ADV
Version 3.1; 02/04

Reset to Defaults

Soil Gas Concentration Data

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Soil gas conc., C_g ($\mu g/m^3$)	OR	ENTER Soil gas conc., C_g (ppmv)	Chemical
127184	1.12E+06			Tetrachloroethylene

MORE ↓

ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Soil gas sampling depth below grade, L_s (cm)	ENTER Average soil temperature, T_S (^oC)	ENTER Thickness of soil stratum A, h_A (cm)	ENTER Thickness of soil stratum B, (Enter value or 0) h_B (cm)	ENTER Thickness of soil stratum C, (Enter value or 0) h_C (cm)	ENTER Soil stratum A SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined stratum A soil vapor permeability, k_v (cm^2)
			Totals must add up to value of Ls (cell F24)					
15	152.4	19.4	152.4			L		

MORE ↓

ENTER Stratum A SCS soil type	ENTER Stratum A soil dry bulk density, ρ_b^A (g/cm^3)	ENTER Stratum A soil total porosity, n^A (unitless)	ENTER Stratum A soil water-filled porosity, θ_w^A (cm^3/cm^3)	ENTER Stratum B SCS soil type	ENTER Stratum B soil dry bulk density, ρ_b^B (g/cm^3)	ENTER Stratum B soil total porosity, n^B (unitless)	ENTER Stratum B soil water-filled porosity, θ_w^B (cm^3/cm^3)	ENTER Stratum C SCS soil type	ENTER Stratum C soil dry bulk density, ρ_b^C (g/cm^3)	ENTER Stratum C soil total porosity, n^C (unitless)	ENTER Stratum C soil water-filled porosity, θ_w^C (cm^3/cm^3)
Lookup Soil Parameters				Lookup Soil Parameters				Lookup Soil Parameters			
L	1.59	0.399	0.148	L	1.59	0.399	0.148	L	1.59	0.399	0.148

MORE ↓

ENTER Enclosed space floor thickness, L_{crack} (cm)	ENTER Soil-bldg. pressure differential, ΔP ($g/cm\text{-}s^2$)	ENTER Enclosed space floor length, L_B (cm)	ENTER Enclosed space floor width, W_B (cm)	ENTER Enclosed space height, H_B (cm)	ENTER Floor-wall seam crack width, w (cm)	ENTER Indoor air exchange rate, ER (1/h)	ENTER Average vapor flow rate into bldg. OR Leave blank to calculate Q_{soil} (L/m)
15	40	1000	1000	244	0.1	0.5	5

ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)	ENTER Exposure time ET (hrs/day)
70	30	30	350	24

END

CHEMICAL PROPERTIES SHEET

Diffusivity in air, D_a (cm^2/s)	Diffusivity in water, D_w (cm^2/s)	Henry's law constant at reference temperature, H (atm-m^3/mol)	Henry's law constant reference temperature, T_R (^oC)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (^oK)	Critical temperature, T_C (^oK)	Molecular weight, MW (g/mol)	Unit risk factor, URF ($\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)
7.20E-02	8.20E-06	1.84E-02	25	8,288	394.40	620.20	165.83	5.9E-06	3.5E-02

INTERMEDIATE CALCULATIONS SHEET

Exposure duration, τ (sec)	Source-building separation, L_T (cm)	Stratum A soil air-filled porosity, θ_a^A (cm^3/cm^3)	Stratum B soil air-filled porosity, θ_a^B (cm^3/cm^3)	Stratum C soil air-filled porosity, θ_a^C (cm^3/cm^3)	Stratum A effective total fluid saturation, S_{te} (cm^3/cm^3)	Stratum A soil intrinsic permeability, k_i (cm^2)	Stratum A soil relative air permeability, k_{rg} (cm^2)	Stratum A soil effective vapor permeability, k_v (cm^2)	Floor-wall seam perimeter, X_{crack} (cm)	Soil gas conc. ($\mu g/m^3$)	Bldg. ventilation rate, $Q_{building}$ (cm^3/s)
9.46E+08	137.4	0.251	0.251	0.251	0.257	1.88E-09	0.854	1.61E-09	4,000	1.12E+06	3.39E+04

Area of enclosed space below grade, A_B (cm^2)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. soil temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. soil temperature, H_{TS} (atm-m^3/mol)	Henry's law constant at ave. soil temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm-s)	Stratum A effective diffusion coefficient, D^{eff}_A (cm^2/s)	Stratum B effective diffusion coefficient, D^{eff}_B (cm^2/s)	Stratum C effective diffusion coefficient, D^{eff}_C (cm^2/s)	Total overall effective diffusion coefficient, D^{eff}_T (cm^2/s)	Diffusion path length, L_d (cm)
1.00E+06	4.00E-04	15	9,458	1.35E-02	5.63E-01	1.78E-04	4.53E-03	0.00E+00	0.00E+00	4.53E-03	137.4

Convection path length, L_p (cm)	Source vapor conc., C_{source} ($\mu g/m^3$)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm^3/s)	Crack effective diffusion coefficient, D^{crack} (cm^2/s)	Area of crack, A_{crack} (cm^2)	Exponent of equivalent foundation Peclet number, exp(Pe^f) (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ ($\mu g/m^3$)	Unit risk factor, URF $(\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)
15	1.12E+06	0.10	8.33E+01	4.53E-03	4.00E+02	2.79E+299	6.97E-04	7.82E+02	5.9E-06	3.5E-02

END

RESULTS SHEET

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
1.9E-03	2.1E+01

MESSAGE AND ERROR SUMMARY BELOW: (DO NOT USE RESULTS IF ERRORS ARE PRESENT)

Formulas were altered to incorporate exposure time

SCROLL DOWN TO "END"

END

Attachment A-2
PCE Example of Johnson and Ettinger Model Results for
Soil Gas to Indoor Air for Hypothetical Residential Exposure

CAS #	Chemical	Soil Gas Concentration		EPC Cbuilding ug/m^3	Minimum Cbuilding ug/m^3	Unit risk factor, URF ($\mu g/m^3$)$^{-1}$	CSF (mg/kg/day)$^{-1}$	Reference conc., RfC (mg/m^3)	RfD (mg/kg/day)
		EPC ug/m^3	Minimum ug/m^3						
127184	TETRACHLOROETHENE	1,121,994	16,272	7.82E+02	1.13E+01	5.90E-06	2.07E-02	3.50E-02	1.00E-02

(1) Assumed an average soil temperature of 19.4oC per Figure A-1 in DTSC Indoor Air Guidance (Feb. 2005)
(2) Assumed the soil was loam.
(3) Default exposure frequency and duration of 350 days per year and 30 years typical for a resident and exposure time of 24 hrs/day.
(4) Default building size of 10 meters length, 10 meters width, and 8-foot (244 cm) ceiling height was used.
(5) Building air exchange for resident home of 0.5 per hour.

SG-ADV
Version 3.1; 02/04

Reset to Defaults

Soil Gas Concentration Data

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Soil gas conc., C_g ($\mu g/m^3$)	OR	ENTER Soil gas conc., C_g (ppmv)	Chemical
127184	1.12E+06			Tetrachloroethylene

MORE ↓

ENTER Depth below grade to bottom of enclosed space floor, L_F (cm)	ENTER Soil gas sampling depth below grade, L_s (cm)	ENTER Average soil temperature, T_S (^oC)	ENTER Thickness of soil stratum A, h_A (cm)	ENTER Thickness of soil stratum B, (Enter value or 0) h_B (cm)	ENTER Thickness of soil stratum C, (Enter value or 0) h_C (cm)	ENTER Soil stratum A SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined stratum A soil vapor permeability, k_v (cm^2)
			Totals must add up to value of Ls (cell F24)					
15	152.4	19.4	152.4			L		

MORE ↓

ENTER Stratum A SCS soil type	ENTER Stratum A soil dry bulk density, ρ_b^A (g/cm^3)	ENTER Stratum A soil total porosity, n^A (unitless)	ENTER Stratum A soil water-filled porosity, θ_w^A (cm^3/cm^3)	ENTER Stratum B SCS soil type	ENTER Stratum B soil dry bulk density, ρ_b^B (g/cm^3)	ENTER Stratum B soil total porosity, n^B (unitless)	ENTER Stratum B soil water-filled porosity, θ_w^B (cm^3/cm^3)	ENTER Stratum C SCS soil type	ENTER Stratum C soil dry bulk density, ρ_b^C (g/cm^3)	ENTER Stratum C soil total porosity, n^C (unitless)	ENTER Stratum C soil water-filled porosity, θ_w^C (cm^3/cm^3)
Lookup Soil Parameters				Lookup Soil Parameters				Lookup Soil Parameters			
L	1.59	0.399	0.148	L	1.59	0.399	0.148	L	1.59	0.399	0.148

MORE ↓

ENTER Enclosed space floor thickness, L_{crack} (cm)	ENTER Soil-bldg. pressure differential, ΔP ($g/cm\text{-}s^2$)	ENTER Enclosed space floor length, L_B (cm)	ENTER Enclosed space floor width, W_B (cm)	ENTER Enclosed space height, H_B (cm)	ENTER Floor-wall seam crack width, w (cm)	ENTER Indoor air exchange rate, ER (1/h)	ENTER Average vapor flow rate into bldg. OR Leave blank to calculate Q_{soil} (L/m)
15	40	1000	1000	244	0.1	0.5	5

ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)	ENTER Exposure time ET (hrs/day)
70	30	30	350	24

END

CHEMICAL PROPERTIES SHEET

Diffusivity in air, D_a (cm^2/s)	Diffusivity in water, D_w (cm^2/s)	Henry's law constant at reference temperature, H (atm-m^3/mol)	Henry's law constant reference temperature, T_R (^oC)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (^oK)	Critical temperature, T_C (^oK)	Molecular weight, MW (g/mol)	Unit risk factor, URF ($\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)
7.20E-02	8.20E-06	1.84E-02	25	8,288	394.40	620.20	165.83	5.9E-06	3.5E-02

INTERMEDIATE CALCULATIONS SHEET

Exposure duration, τ (sec)	Source-building separation, L_T (cm)	Stratum A soil air-filled porosity, θ_a^A (cm^3/cm^3)	Stratum B soil air-filled porosity, θ_a^B (cm^3/cm^3)	Stratum C soil air-filled porosity, θ_a^C (cm^3/cm^3)	Stratum A effective total fluid saturation, S_{te} (cm^3/cm^3)	Stratum A soil intrinsic permeability, k_i (cm^2)	Stratum A soil relative air permeability, k_{rg} (cm^2)	Stratum A soil effective vapor permeability, k_v (cm^2)	Floor-wall seam perimeter, X_{crack} (cm)	Soil gas conc. ($\mu g/m^3$)	Bldg. ventilation rate, $Q_{building}$ (cm^3/s)
9.46E+08	137.4	0.251	0.251	0.251	0.257	1.88E-09	0.854	1.61E-09	4,000	1.12E+06	3.39E+04

Area of enclosed space below grade, A_B (cm^2)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. soil temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. soil temperature, H_{TS} (atm-m^3/mol)	Henry's law constant at ave. soil temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm-s)	Stratum A effective diffusion coefficient, D^{eff}_A (cm^2/s)	Stratum B effective diffusion coefficient, D^{eff}_B (cm^2/s)	Stratum C effective diffusion coefficient, D^{eff}_C (cm^2/s)	Total overall effective diffusion coefficient, D^{eff}_T (cm^2/s)	Diffusion path length, L_d (cm)
1.00E+06	4.00E-04	15	9,458	1.35E-02	5.63E-01	1.78E-04	4.53E-03	0.00E+00	0.00E+00	4.53E-03	137.4

Convection path length, L_p (cm)	Source vapor conc., C_{source} ($\mu g/m^3$)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm^3/s)	Crack effective diffusion coefficient, D^{crack} (cm^2/s)	Area of crack, A_{crack} (cm^2)	Exponent of equivalent foundation Peclet number, exp(Pe^f) (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ ($\mu g/m^3$)	Unit risk factor, URF $(\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)
15	1.12E+06	0.10	8.33E+01	4.53E-03	4.00E+02	2.79E+299	6.97E-04	7.82E+02	5.9E-06	3.5E-02

END

RESULTS SHEET

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
1.9E-03	2.1E+01

MESSAGE AND ERROR SUMMARY BELOW: (DO NOT USE RESULTS IF ERRORS ARE PRESENT)

Formulas were altered to incorporate exposure time

SCROLL DOWN TO "END"

END

Attachment A-1
PCE data for Calculations of 95UCL for Omega Site Data 5 to 6 feet bgs and 5 to 30 ft bgs

Soil Gas 5-6 ft bgs for Site Parcel

SAMPLE_ID	TETRACHLOROETHENE ug/m^3
OC-SG-006-VP19-121305	16272
OC-SG-06-04-041204	284760
OC-SG-06-05-041204	1559400
OC-SG-06-06-041204	1457700
OC-SG-06-07-041304	311880
OC-SG-06-08-0413104	813600
OC-SG-06-09-041304	678000
OC-SG-06-10-041304	1288200
OC-SG-06-11-041304	881400
OC-SG-06-12-041204	1491600

	TETRACHLOROETHENE
min	16,272
average	878,281
max	1,559,400
count	10
location of max	OC-SG-06-05-041204
95 UCL	1,121,994

Soil Gas 5-30 ft bgs for Site Parcel

SAMPLE_ID	TETRACHLOROETHENE ug/m^3
OC-SG-06-04-041204	284760
OC-SG-12-04-041204	230520
OC-SG-06-05-041204	1559400
OC-SG-12-05-041204	244080
OC-SG-06-06-041204	1457700
OC1-LC6-G-0-9	1491600
OC-SG-12-06-041204	2305200
OC-SG-06-07-041304	311880
OC-SG-12-07-041304	325440
SG-7-18FT	149160
OC1-SG7B-G-0-26	58308
SG-7-24FT	62376
OC-SG-06-08-0413104	813600
OC-SG-12-08-041304	10848
OC1-SG8A-G-0-25	881400
SG-8-18FT	284760
SG-8-24FT	26442
OC-SG-06-09-041304	678000
OC1-LC9-G-0-10	67800
OC-SG-12-09-041304	183060
OC1-SG9A-G-0-27	332220
SG-9-18FT	237300
SG-9-24FT	488.16
OC-SG-06-10-041304	1288200
OC-SG-12-10-041304	244080
OC1-SG10A-G-0-22	796650
SG-10-18FT	298320
SG-10-24FT	210180
OC-SG-06-11-041304	881400
OC-SG-12-11-041304	813600
OC1-SG11A-G-0-24	623760
SG-11-18FT	176280
SG-11-24FT	549180
OC-SG-06-12-041204	1491600
OC-SG-12-12-041204	74580
OC-SG-006-VP19-121305	16272
OC-SG-012-VP19-121305	13560
OC-SG-018-VP19-121305	3254.4
OC-SG-024-VP19-121305	1898.4

Data	95 UCL ug/m3
Soil Gas 5-6 ft bgs for Site Parcel	1,121,994
Soil Gas 5-30 ft bgs for Site	733,374

	TETRACHLOROETHENE
min	488
average	499,466
max	2,305,200
count	39
location of max	OC-SG-12-06-041204
95 UCL	733,374

Attachment A-1
ProUCL Output for Soil Gas 5 to 6 ft bgs for Site Parcel

Data File Soil Gas 5-6 ft bgs for Site Parcel Variable: TETRACHLOROETHENE

Raw Statistics	
Number of Valid Samples	11
Number of Unique Samples	11
Minimum	0
Maximum	1559400
Mean	798437.5
Median	813600
Standard Deviation	592075.9
Variance	3.51E+11
Coefficient of Variation	0.741543
Skewness	-0.036343

Normal Distribution Test	
Shapiro-Wilk Test Statisitic	0.905074
Shapiro-Wilk 5% Critical Value	0.85
Data are normal at 5% significance level	

95% UCL (Assuming Normal Distribution)	
Student's-t UCL	1121994

Gamma Statistics Not Available

Lognormal Statistics Not Available

RECOMMENDATION
Data are normal (0.05)
Use Student's-t UCL
1121994

95% Non-parametric UCLs	
CLT UCL	1092073
Adj-CLT UCL (Adjusted for skewness)	1089983
Mod-t UCL (Adjusted for skewness)	1121668
Jackknife UCL	1121994
Standard Bootstrap UCL	1080606
Bootstrap-t UCL	1120754
Hall's Bootstrap UCL	1062753
Percentile Bootstrap UCL	1073952
BCA Bootstrap UCL	1073705
95% Chebyshev (Mean, Sd) UCL	1576578
97.5% Chebyshev (Mean, Sd) UCL	1913279
99% Chebyshev (Mean, Sd) UCL	2574665

Attachment A-1
ProUCL Output for Soil Gas 5 to 30 ft bgs for Site Parcel

Data File Soil Gas 5-30 ft bgs for Site Parcel Variable: TETRACHLOROETHENE

Raw Statistics	
Number of Valid Samples	39
Number of Unique Samples	34
Minimum	488.16
Maximum	2305200
Mean	499465.6
Median	284760
Standard Deviation	558576.5
Variance	3.12E+11
Coefficient of Variation	1.118348
Skewness	1.466778

Gamma Statistics	
k hat	0.610087
k star (bias corrected)	0.580251
Theta hat	818679
Theta star	860774.4
nu hat	47.5868
nu star	45.25961
Approx.Chi Square Value (.05)	30.82413
Adjusted Level of Significance	0.0437
Adjusted Chi Square Value	30.35343

Log-transformed Statistics	
Minimum of log data	6.190643
Maximum of log data	14.65068
Mean of log data	12.11101
Standard Deviation of log data	1.964865
Variance of log data	3.860693

RECOMMENDATION

Data follow gamma distribution (0.05)

Use Approximate Gamma UCL

733373.9

Normal Distribution Test	
Shapiro-Wilk Test Statisitic	0.810852
Shapiro-Wilk 5% Critical Value	0.939
Data not normal at 5% significance level	

95% UCL (Assuming Normal Distribution)	
Student's-t UCL	650263.7

Gamma Distribution Test	
A-D Test Statistic	0.37275
A-D 5% Critical Value	0.802319
K-S Test Statistic	0.096807
K-S 5% Critical Value	0.148325
Data follow gamma distribution	
at 5% significance level	

95% UCLs (Assuming Gamma Distribution)	
Approximate Gamma UCL	733373.9
Adjusted Gamma UCL	744746.5

Lognormal Distribution Test	
Shapiro-Wilk Test Statisitic	0.885169
Shapiro-Wilk 5% Critical Value	0.939
Data not lognormal at 5% significance level	

95% UCLs (Assuming Lognormal Distribution)	
95% H-UCL	4010814
95% Chebyshev (MVUE) UCL	3218266
97.5% Chebyshev (MVUE) UCL	4134023
99% Chebyshev (MVUE) UCL	5932851

95% Non-parametric UCLs	
CLT UCL	646587.6
Adj-CLT UCL (Adjusted for skewness)	669034.8
Mod-t UCL (Adjusted for skewness)	653765.1
Jackknife UCL	650263.7
Standard Bootstrap UCL	647370.5
Bootstrap-t UCL	681394.3
Hall's Bootstrap UCL	685808.2
Percentile Bootstrap UCL	649609.5
BCA Bootstrap UCL	671595.5
95% Chebyshev (Mean, Sd) UCL	889342.1
97.5% Chebyshev (Mean, Sd) UCL	1058042
99% Chebyshev (Mean, Sd) UCL	1389420